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DYNAMICS OF INTRUSIONS

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LONG-TERM GOALS

My long-term goal is to understand small-scale mixing processes such as internal waves, double-diffusion, and intrusions and to determine their influence on the larger-scale dynamics.

OBJECTIVES

The objectives of this project are to examine the evolution and dynamics of intrusions, especially after the initial growth phase, and to determine when non-linear effects become important and how they affect the properties and evolution of the intrusions. What are the dynamical balances of the intrusions at this time? How do these results depend on the choice of the parameterization for the sub-intrusion-scale mixing processes (both double-diffusively- and turbulently-driven)?

APPROACH

The dynamics of the intrusions are studied using a finite difference primitive equation model (SPEM 5.1), which has the capability of using eddy diffusivity coefficients that can vary with time and location as well as being different for heat, salt and momentum. These coefficients can be functions of the flow field.

Two-dimensional simulations are being performed. In these studies, the background salinity and temperature are linear in both the vertical and horizontal directions. However, there is no horizontal gradient in density since, in terms of density, horizontal changes in temperature are compensated by horizontal changes in salinity. These conditions are the same as the theoretical initial perturbation studies of double-diffusively-driven intrusions. An initial (white noise) perturbation of salinity and temperature (although not in density) is made in the central region of the model (either at a single horizontal grid point or a finite band).

WORK COMPLETED

A linear stability analysis of turbulently (with unequal diffusivities for salt and heat) driven intrusions has been undertaken. A comparison of intrusion properties (e.g., growth rates) of turbulently-driven intrusions (using either a flux ratio or diffusivity ratio parameterization for salt and heat) to double-diffusively-driven intrusions have been made. These instability analyses are used to check the validity of the model configurations.

Simulations with several mixing parameterizations are being undertaken. The first is to use a constant diffusivity for salt and a constant flux ratio to determine the vertical heat flux. This parameterization is the basis of the initial instability analysis of salt-finger-driven intrusions (Toole and Georgi 1981; McDougall 1985). The second set of experiments still have a constant flux ratio but a diffusivity coefficient for salt that depends on the density-ratio, a measure of salt-fingering-favourable conditions (Walsh and Ruddick 1995). Finally, the third set of related experiments use both a salt diffusivity and flux ratio that depend on the density-ratio. An analysis of these model runs are underway,

RESULTS

Unequal diffusivities for salt and heat drive intrusions. These unequal diffusivities can be due to either double-diffusive mixing or incomplete turbulent mixing. The latter process can generate intrusions in almost all types of stratification unlike the former process which needs a double-diffusively unstable stratification. At this time, the relative importance of the two processes is unknown. For reasonable choices of the turbulent mixing coefficients, it is possible that intrusions generated by the turbulent mixing can dominate those generated by salt-fingers in the regime of weak salt-fingering favourable stratification (Hebert 1997). However, much further work is needed on this topic.

The linear stability analysis has been used to confirmed that the model simulations are adequately reproducing the initial growth rate of the intrusions. Thus, we are confident that the later evolution of the intrusions are being adequately modelled.

IMPACT/APPLICATIONS

The observation of intrusions in almost all frontal regions implies that they must be an important mechanism for cross-frontal fluxes. It has been shown that incomplete turbulent mixing can drive intrusions. Until we have a better understanding of this process, we cannot determine whether turbulent mixing could dominate double-diffusive mixing after intrusions have developed.

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